NOTES

ADDITIONAL EVIDENCE SUBSTANTIATING EXISTENCE OF NORTHERN SUBPOPULATION OF NORTHERN ANCHOVY, *ENGRAULIS MORDAX*

The northern anchovy, *Engraulis mordax* (Girard), ranges from Queen Charlotte Islands, British Columbia, to Cape San Lucas, lower Baja California. A study of variations in meristic characters (McHugh 1951) and genetic studies using serum transferrins (Vrooman and Smith 1971) generally support the hypothesis that three distinct subpopulations exist within this species' total geographic range. The dividing lines between subpopulations apparently occur at Point Conception, Calif. (delineating the northern and central elements), and at Cedros Island, central Baja California (delineating the central and southern elements).

Extensive spawning activity by the central and southern subpopulations is evidenced from the results of comprehensive egg and larvae surveys conducted since 1951 by the California Cooperative Oceanic Fisheries Investigations (Baxter 1967). Although these surveys suggest that the time-space distributions of spawning effort by these two subpopulations tend to overlap, evidently each achieves enough reproductive isolation to generate genetic differences between serum transferrins. Apparently, then, the central and southern subpopulations are capable of independently producing their own recruitment.

Until recently, the evidence for independent spawning by the northern subpopulation was not extensive. Ahlstrom (1968) noted that, in 1949 and 1950, anchovy larvae were found in moderate abundance off the Oregon coast. LeBrasseur (1970) indicated that a small number of larvae were taken in a 1958 survey of Queen Charlotte Sound, British Columbia. Waldron[1] stated that no eggs or larvae were taken in incidental samples off the Washington-Oregon coast in 1966 but that a few anchovy larvae were obtained during a comprehensive survey in the spring of 1967.

[1]Waldron, K. D., Northwest Fisheries Center, National Marine Fisheries Service, NOAA, Seattle, Wash., pers. commun. 1971.

Such meager results might lead one to believe that the few larvae observed in northern waters were merely the result of incidental spawning activity. A conclusion might then be made that the northern subpopulation does not independently produce its own recruitment but relies instead upon an influx of anchovies from the two southern subpopulations.

In 1969, however, Richardson (1973) encountered such extensive numbers of anchovy larvae during a May-October survey of larval fishes off the Oregon coast (lat. 42°00'-46°30'N, coastline—long.129°30'W) that the above conclusions seemed to be refuted. Her results indicated the presence of a spawning stock of anchovies associated with the warm, near-surface waters of the Columbia River plume. Moreover, the peak of spawning seemed to be correlated with that period in summer when warm plume water (>14°C) was a dominant oceanographic feature.

Evidence from Length-Frequency Distributions

An analysis of age- and length-frequency distributions played a major role in determining stock structure for the Pacific sardine, *Sardinops sagax*. A similar analysis of length-frequency distributions was undertaken for the northern anchovy. The following review outlines the rationale and criteria applied in the sardine analysis and adapted for this study.

Early sardine investigators at first hypothesized that three subpopulations composed this species' total west coast population[2]. However, in addition to evidence of only sporadic spawning activity (Ahlstrom 1954), age- and length-frequency distributions obtained from the so-called northern subpopulation failed to reveal the presence of the most recently produced age-groups, i.e., the 0's, 1's, and 2's (Harry 1948). These ages, however, were often observed in samples from the central and southern subpopulations. The consistent absence of 0's from northern samples presumably confirmed a lack

[2]A northern subpopulation supposedly ranged from British Columbia southward to central California, while central and southern subpopulations resided respectively off southern California and lower Baja California.

of independent spawning activity by that subpopulation of sardines (Harry 1949). The consistent presence of 0's, of course, would have indicated that independent spawning had occurred.

Figure 1 presents the length-frequency distributions analyzed in this study. These anchovy lengths were obtained from four exploratory fishing surveys conducted from Cape Flattery, Wash., to Yaquina Bay, Oreg., during 1966-67. These surveys occasionally encountered schools of anchovies containing small fish which became gilled in the meshes of the survey gear (Figure 2). It was speculated that these small anchovies were the result of recent spawning activity in the Washington-Oregon area.

To analyze these length distributions, one must first know the range of lengths associated with individuals belonging to age-group 0. Clark and Phillips (1952) indicated that 0-age anchovies begin entering the southern California live-bait fishery at lengths ranging from 5 to 9 cm. Miller (1955) stated that 0-age fish begin entering the southern California commercial fishery at 8.5-9.0 cm. Tillman (1972) concluded that anchovies are at least 6 mo old when they enter the commercially exploitable population at 9 cm. Figure 3 presents the ranges, medians, and median quartiles of the lengths of anchovy larvae obtained by Richardson (1973). These indicate that, in the northern subpopulation, 0-age anchovies approach 6 cm after 5 mo of growth. Thus, a length range of 0-9 cm should define those anchovies which resulted from spawning, at least, during the past 6 mo. This range was used to define the 0-age component in all length-frequency distributions.

Applying this criterion, the bar graphs of Figure 1 indicate that 0-age anchovies indeed were present in the northern subpopulation during the years surveyed. Lengths less than 4 cm were not found, but the 4-9 cm range composed, respectively, 11.6, 19.8, 87.0, and 39.0% of these four length-frequency distributions. The results shown for November-December 1966 and February 1967 are particularly striking, having major modes located respectively at 6 and 5.5 cm. These latter two distributions result from the facts that anchovies tend to school by size and that the later 1966 and early 1967 surveys primarily encountered schools of small fish. Therefore, following the rationale discussed at the beginning of this section, the presence of such juveniles would tend to confirm the

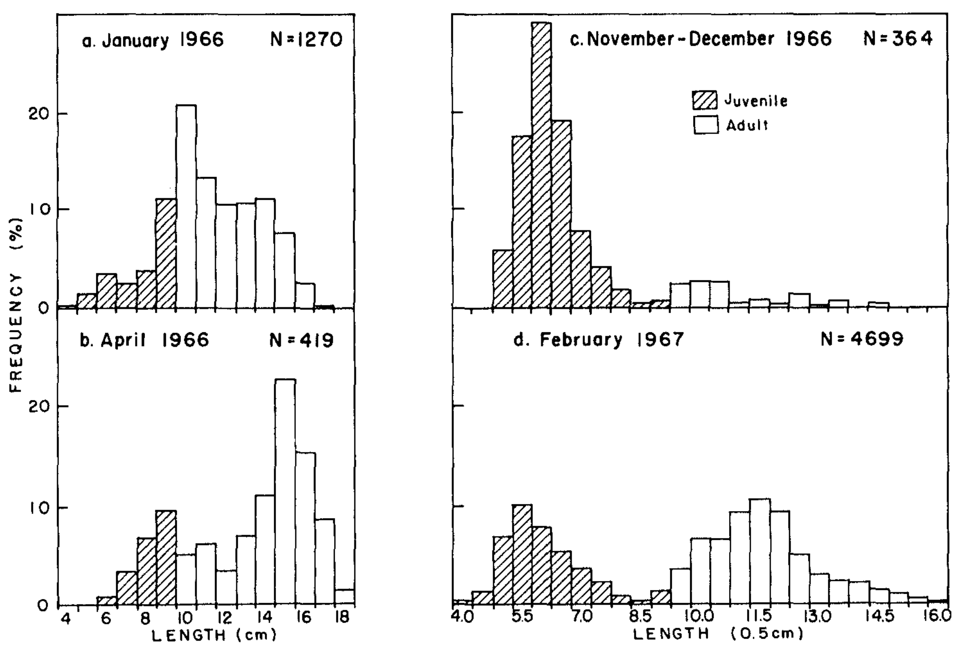

FIGURE 1.—Composite length-frequency distributions of juvenile and adult northern anchovy sampled off Washington-Oregon during 1966-67.

FIGURE 2.—Juvenile northern anchovy gilled in the meshes (½-¾ inch) of a mid-water trawl off the Washington-Oregon coast.

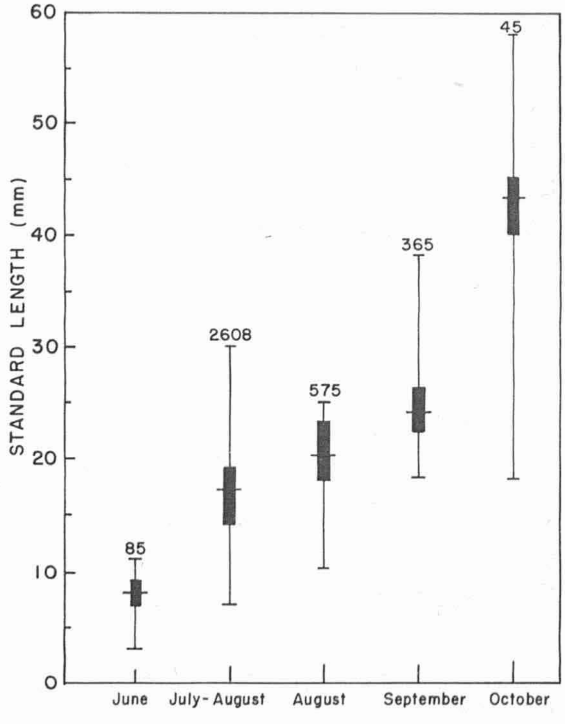

FIGURE 3.—Ranges, medians, and median quartiles of lengths of northern anchovy larvae obtained during May-October 1969 off Oregon (Richardson 1973).

occurrence of independent spawning activity by the northern subpopulation of anchovies.

Discussion

Figure 1 gives the results of surveys which took place during the winter or spring. Since the northern subpopulation apparently spawns during the summer, then these figures indicate that spawning occurred during the summer which preceded each survey period. In other words, Figure 1a and b indicate that spawning occurred during the summer of 1965, resulting in recruitment of 0-age fish during January-April 1966. Moreover, Figure 1c and d indicate that spawning occurred in the summer of 1966, resulting in recruitment during November 1966-February 1967. Thus, according to Richardson's data and this analysis, independent spawning by the northern subpopulation seems to have occurred quite regularly rather than incidentally (occurring at least in 1965, 1966, and 1969).

Consequently, it is concluded that the presence of anchovies in northern waters does not represent a mere expansion of this species' geographic range—an expansion that well might have accompanied its recent fivefold increase in total population size. The previously mentioned genetic and meristic evidence, the results of recent larvae surveys, and the above length-frequency analysis would all seem to refute such a conclusion. Moreover, since this subpopulation was the mainstay of a substantive fishery for live bait during the 1940's (Pruter 1966), it seems to have been a persistent feature of the Washington-Oregon coast even before the dramatic expansion of the anchovy biomass which followed the demise of the sardine. Thus the weight of evidence seems to indicate that the northern subpopulation of anchovies is one of three independent population elements, all of which are capable of spawning and producing their own recruitment.

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COMMENT. INTRODUCTION OF *CODIUM* IN NEW ENGLAND WATERS

Genus *Codium* is one of the most common forms of seaweed found in almost every latitude but, until recently, has been absent from the east coast of North America. *Codium* attaches to rocks, pilings, old molluscan shells, and also shells of living oysters, scallops, and mussels. This algae has a number of common names, such as spaghetti grass, staghorn, deadman's fingers, and Japanese weed. It grows rapidly and often becomes so dense that it sometimes creates undesirable conditions on cultivated and natural shellfish beds, as well as in some other environments. At times it becomes buoyant enough to float and to carry along with it mollusks, to the shells of which it is attached. Mass mortalities of *Codium* are usually followed by quick decomposition, creating adverse conditions that result in the death of mollusks and other bottom forms.

No *Codium* was known to exist in New England waters until approximately the end of the 1950's, when the first specimens of *Codium fragile* were reported from several aquatic areas adjacent to Long Island. Since then it has become established in the waters of New England, spreading as far north as the State of Maine. According to a recent article (Quinn 1971) "It is now a dominant seaweed in the waters of Eastern Long Island and